Thesis/
Reports
Fornwalt,
P.J.

SHORT-TERM EFFECTS OF FIRE AND POSTFIRE REHABILITATION ON THE FOREST UNDERSTORY: A CASE STUDY FROM THE COLORADO FRONT RANGE

04-CO-11221611-257

Short-term effects of fire and postfire rehabilitation on the forest understory: a case study from the Colorado Front Range

A Final Report to the National Commission on Science for Sustainable Forestry
NCSSF Research Project C4.3

January 31, 2006

Principal Investigator: Paula J. Fornwalt, Ecologist
US Forest Service, Rocky Mountain Research Station
240 West Prospect Road, Fort Collins, CO 80525
970-498-2581
pfornwalt@fs.fed.us

Co-Principal Investigator: Merrill R. Kaufmann, Research Forest Ecologist (emeritus)
US Forest Service, Rocky Mountain Research Station
240 West Prospect Road, Fort Collins, CO 80525
970-282-0163
mkaufmann@fs.fed.us

National FS Library
USDA Forest Service

MAY 9 2008

240 W Prospect Rd
Fort Collins CO 80526

The research described in this report was funded by the National Commission on Science for Sustainable Forestry (NCSSF), the Joint Fire Science Program (JFSP), and the Rocky Mountain Research Station (RMRS).

The National Council on Science and the Environment (NCSE) conducts the NCSSF program with support from the Doris Duke Charitable Foundation, the David and Lucile Packard Foundation, the Surdna Foundation, and the National Forest Foundation.

This report was written and prepared by U.S. government employees on official time, and therefore it is in the public domain and not subject to copyright.

Table of Contents

Abstract
Land managers often rehabilitate intensely-burned areas to minimize immediate postfire erosion and surface runoff. While these rehabilitation treatments may have positive effects on erosion-related issues, they may also affect the short-term regeneration, establishment, and growth of understory plants. To quantify the effect of rehabilitation treatments on the forest understory, we compared a suite of understory response variables between unburned, burned, and burned-and-rehabilitated plots in and around the 2002 Hayman Fire.

The postfire rehabilitation treatment evaluated in this study was a seed-and-scarify treatment, which was completed shortly after the fire and covered approximately 5,300 of the 13,200 hectares rehabilitated by the U.S. Forest Service. In general, the intensity of the treatment was low. Of the two annual grass species seeded, only one germinated in our plots, providing less than one percent cover. While the intensity of the soil scarification treatment could not be assessed, we suspect that it was also low, as there were no visible signs of it remaining in 2004.

We found that the Hayman Fire had some effect on the structure of the understory plant community as a whole and on the distribution and abundance of individual species within the community. However, the seed-and-scarify treatment within the Hayman Fire had little additional effect. Both native species richness and cover were not significantly different between unburned, burned, and burned-and-rehabilitated plots. Non-native species richness and cover were generally higher in burned and burned-and-rehabilitated plots than in unburned plots, but no effect of the postfire rehabilitation treatment *per se* could be detected. When we assessed the effects of the fire $^{+}$/- postfire rehabilitation on a suite of individual species, the findings varied by species. Most of these species were tolerant of the fire $^{+}$/- postfire rehabilitation, but stimulated and sensitive species were also found. The regeneration success of each species was often related to its life history and postfire regeneration strategy.

It is not likely that the seed-and-scarify postfire rehabilitation treatment met the goals of the Forest Service, since the treatment did not appear to reduce erosion (though we did not measure erosion in this study). While the forest understory was not additionally affected by seed-and-scarify rehabilitation treatment in the Hayman Fire, results may have been different if the treatment had been more successful. Because we did not measure erosion in this study, and because the seed-and-scarify treatment has not been studied in other Front Range fires (or elsewhere), we are uncomfortable with making a recommendation on whether or not local land managers should continue to implement this postfire rehabilitation treatment in the future. However, our results do suggest that this type of treatment needs further scrutiny before it is used extensively under similar conditions. Furthermore, we strongly feel that if Front Range land managers continue to implement this postfire rehabilitation treatment, its effects on the understory plant community must also be monitored to determine the relationship between treatment success and understory response.

Deliverables include (1) a final report to NCSSF; (2) a manuscript to a peer-reviewed journal; (3) a technical report and PowerPoint summary to forest managers; (4) presentations at meetings and conferences; and (5) non-technical articles to publications read by targeted users.

Short-term effects of fire and postfire rehabilitation on the forest understory: a case study from the Colorado Front Range

Introduction

High-severity fires can greatly increase runoff and erosion potential in coniferous forests by changing vegetation, litter, and soil structure. Damage caused by increased postfire runoff and erosion can be extensive and costly, especially when both ecosystem dynamics and human values are affected (Beyers 2004). Consequently, land managers often prescribe emergency rehabilitation treatments to minimize the risk of erosion-related damage. These rehabilitation treatments are often implemented over large portions of intensely burned landscapes shortly after the fire is contained. Many of the common postfire rehabilitation treatments aim to reduce runoff and erosion potential by increasing ground cover (e.g., seeding with understory species; mulching with straw), by breaking up the hydrophobic soil layer (e.g., soil scarification with rakes or specially designed machinery), or by providing traps to capture sediment as it moves downhill (e.g., placing logs or straw bales along hillside contours or in drainages).

Several factors converge to make the Upper South Platte Watershed of Colorado extremely susceptible to postfire erosion. The first factor is the shift in the historical fire regime as a result of the unnatural fuel buildup since Euro-American settlement in the mid-1880s. The forests of the Upper South Platte Watershed are generally dominated by ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*), and have historically burned with a mixed-severity fire regime which created a complex spatial and temporal mosaic of forest age and density (Brown et al. 1999). However, over a century of fire suppression, logging, and grazing has homogenized the forest structure across the landscape, and dense, young stands are widespread. As a result, the fire regime has shifted to one of low frequency and high severity, which is likely outside the natural range of variability for this system (Kaufmann et al. 2001).

Other factors that contribute to the high risk of postfire erosion in the Upper South Platte Watershed relate to the topography, soils, and climate of the region. Topography in the Upper South Platte Watershed is steep and dissected in many locations, with some slopes reaching more than 50 percent (Finney et al. 2003). The shallow granitic soils common throughout the Upper South Platte Watershed are some of the most erosive in the country. Short, intense rain events are also quite common during the summer months in this region, and can cause substantial amounts of erosion in susceptible areas.

Since the mid-1990's, the Upper South Platte Watershed has experienced a series of large and severe wildfires with a significant amount of postfire sediment movement. All of these fires occurred partly in the wildland/urban interface, where human values were at risk from both fires and subsequent flooding and erosion. To date, the largest and most severe fire known to burn in the Upper South Platte Watershed was the Hayman Fire of 2002. The Hayman Fire was the largest in Colorado's recorded history, encompassing 55,850 ha. Approximately half of the area burned as a stand-replacing crown fire, much of it in a single day of extreme weather. Largely in an effort to mitigate erosion risk and

other erosion-related problems, managers on the Pike National Forest rehabilitated much of the burned area. In total, approximately 12,800 ha of the Hayman Fire were rehabilitated on Forest Service land over the next year, by mulching, scarifying, seeding, and/or other treatments (Robichaud et al. 2003).

These rehabilitation treatments may affect much more than runoff and erosion. For example, what are the effects of these postfire emergency rehabilitation treatments on understory plant communities? Studies designed to address this question are uncommon, and have generally focused on a few select ecosystems and rehabilitation treatment types. For instance, several studies have examined the effects of postfire seeding on California chaparral and on the coniferous forests of the northwest United States (see Beyers 2004 for a comprehensive literature review). However, studies looking at how other types of postfire rehabilitation treatments (besides seeding) affect the understory community are sparser, as are studies in other regions of the United States. Furthermore, studies of this sort are non-existent for any type of postfire rehabilitation treatment in the Colorado Front Range. As wildfires continue to occur in the Front Range, and as rehabilitation treatments expand to proportionately larger land areas, local managers and researchers are expressing the need for data to help them understand the effects of wildfire and subsequent postfire rehabilitation on the forest understory.

Purpose

This research project investigated the short-term effects of wildfire and postfire rehabilitation on the forest understory by comparing a suite of understory response variables between unburned, burned, and burned-and-rehabilitated plots in and around the 2002 Hayman Fire. Though many different postfire rehabilitation treatments were implemented within the area burned by the Hayman Fire, we focused on the seed-and-scarify rehabilitation treatment, which comprised 5,300 of the 12,800 ha treated. Specifically, we addressed three questions:

<u>What are the effects of wildfire and postfire rehabilitation on the native species?</u> Understanding the effects of fire and postfire rehabilitation on the native flora is critical if we wish to preserve biodiversity and ecosystem function after these disturbances. Throughout the western United States, the native flora has evolved with fire and many of the species have postfire regeneration strategies that allow them to re-establish quickly after fire. Thus, the response of the native plant species may provide a good indicator of ecosystem recovery after disturbance.

<u>What are the effects of wildfire and postfire rehabilitation on non-native invaders?</u> Non-native species may have adverse effects in many systems, such as displacing native species, changing fire regimes, and altering nutrient cycles. Fire and postfire rehabilitation may benefit non-native species by creating favorable habitats for germination, establishment and growth. Furthermore, fire fighting and postfire rehabilitation activities have the potential to introduce non-native species from contaminated rehabilitation materials, equipment and machinery.

What are the effects of wildfire and postfire rehabilitation on other species of concern?
We analyzed fire effects on three categories of plants. First, we explored the effects of fire on the main food plants of the Pawnee montane skipper (*Hesperia leonardus montana*), a threatened butterfly species that is found only in the ponderosa pine forests of the Upper South Platte Watershed (U.S. Fish and Wildlife Service 1998). Butterfly larvae feed exclusively on blue grama (*Bouteloua gracilis*), and adults preferentially feed on the nectar of dotted blazing star (*Liatris punctata*). Second, we analyzed the effects of fire on any plants encountered in our study sites that are considered to be threatened, endangered, rare, sensitive, or otherwise of concern at the Federal, state, or local level. Third, we analyzed the effects of fire on those plants considered to be noxious weeds by the state of Colorado.

Summary of Results

The postfire rehabilitation treatment
Overall, the intensity of the seed-and-scarify postfire rehabilitation treatment was low. Seeded grasses were present in both the burned-only and the burned-and-rehabilitated plots after the fire, but were not present in the unburned reference plots. Of the two grasses seeded by the Forest Service, only triticale (*Triticosecale rimpaui*, a wheat-rye hybrid) was found in our burned plots; barley (*Hordeum vulgare*) was never encountered. Triticale cover was less than one percent in both burned sites, but was marginally higher in the burned-and-rehabilitated site than in the burned-only site. While the intensity of the soil scarification treatment could not be assessed, we suspect that it was also low, as there were no visible signs of it remaining in 2004.

Other upland portions of the Hayman Fire that were rehabilitated with the seed-and-scarify treatment also had low seeded grass establishment and no visible signs of scarification (Fornwalt personal observation), suggesting that our area was representative of the larger treated area of the Hayman Fire. We suspect that the unfavorable weather conditions during 2003 and 2004 were at least partially responsible for low seeded grass germination on upland slopes. The summer of 2003 was one of the warmest and driest on record in the Colorado Front Range, and many ungerminated seeds and germinated seedlings may have been killed. During the summer of 2004, intense flash floods throughout both burned and unburned portions of the South Platte Basin may have washed away much of the remaining viable seed.

Effects on native and non-native species richness and cover
We saw little effect of the postfire rehabilitation treatment on native and non-native species richness and cover, though we did see some effects of the burn in general. This may be the result of low treatment intensity and also of the adaptations that many of the plants have to survive or successfully regenerate after disturbance.

Both native species richness and native species cover were not significantly different between the burned-only, burned-and-rehabilitated, and reference sites. Furthermore, pre-fire native richness and cover values for the burned-only site (measured in 1996/7) were also similar to the 2004 values for the three site types (Fornwalt et al. 2003).

Non-native species richness and cover were low overall, but was generally higher in burned plots than in unburned plots. No effect of the postfire rehabilitation treatment *per se* could be detected. Pre-fire non-native species richness and cover for the burned-only site were very similar to values recorded in the reference sites, suggesting that changes in non-native richness and cover were a result of the fire and not an artifact of study site variability. These findings also suggest that fire fighting and postfire rehabilitation activities did not likely introduce non-native species from contaminated rehabilitation materials, equipment and machinery.

<u>Effects on native and non-native dominants</u>

For this study, we defined a dominant understory species as one that occurs in all plots of at least one study site. By this definition, thirteen plants were classified as dominant native species:

1. Nodding onion (*Allium cernuum*),
2. Small-leaf pussytoes (*Antennaria parvifolia*),
3. Fendler's rockcress (*Arabis fendleri*),
4. White sagebrush (*Artemisia ludoviciana*),
5. Ross' sedge (*Carex rossii*),
6. Fremont's goosefoot (*Chenopodium fremontii*),
7. Narrowleaf goosefoot (*Chenopodium leptophyllum*),
8. Hairy false goldenaster (*Heterotheca villosa*),
9. Prairie bluebells (*Mertensia lanceolata*),
10. Mountain muhly (*Muhlenbergia montana*),
11. Fendler's ragwort (*Packera fendleri*),
12. Bigflower cinquefoil (*Potentilla fissa*), and
13. Soapweed yucca (*Yucca glauca*).

We analyzed two variables for each plant: the frequency of each species (defined as the number of subplots per plot in which the species occurred), and the percent cover of each species within a plot. By comparing average frequency and cover in the burned-only, burned-and-rehabilitated, and reference sites, we were able to classify each understory plant in one of three ways: (a) tolerant— the species' distribution and abundance were unaffected by the fire $^{+}$/- the postfire rehabilitation treatment; (b) stimulated— the species' distribution and abundance were positively affected by the fire $^{+}$/- the rehabilitation treatment; or (c) sensitive— the species' distribution and abundance were negatively affected by the fire $^{+}$/- the rehabilitation treatment.

Most of the dominant species were tolerant of both the fire and the postfire rehabilitation treatment, neither increasing nor decreasing significantly in frequency or cover. This finding is not surprising when the historical disturbance regime of the area and the life histories of the individual plants are considered. A review of the current literature for each tolerant species revealed that each has evolved a mechanism (or mechanisms) for re-establishing after fire, though more information is known for some species than for others. Mechanisms for postfire re-establishment included sprouting (white sagebrush, hairy false goldenaster), establishing from offsite seed sources (small-leaf pussytoes,

Fendler's ragwort, bigflower cinquefoil), or a combination of mechanisms (Ross' sedge is known to sprout and colonize from the seedbank). Furthermore, all of the tolerant species are perennial. We suspect that many of the less-common perennial native species we encountered in our plots would also be tolerant of fire.

Three of the disturbance-stimulated species are short-lived annuals or biennials: Fremont's goosefoot, narrowleaf goosefoot, and mullein. All of these species establish after disturbance from onsite or offsite seed sources, and are common in disturbed areas (Bartos and Mueggler 1981; Rutledge and McLendon 1996; Stickney and Campbell 2000; Wang and Kemball 2005). Fremont's goosefoot and mullein were stimulated by the fire only, with no additional effect of the postfire rehabilitation treatment. The frequency of narrowleaf goosefoot did appear to be more stimulated by the combination of fire and postfire rehabilitation than just by the fire alone; however, cover was not increasingly stimulated by the rehabilitation treatment. Many studies have found that immediately after fire or other disturbance, annuals and biennials are ubiquitous throughout the disturbed area. As time since disturbance increases, they become less common on the landscape as they give way to slower-growing but longer-lived species (Halpern 1989; Stickney 1990). We suspect that this will be the case with these three short-lived species, as well as with other functionally similar but less-common species.

The other two disturbance-stimulated species are perennial: Fendler's rockcress and prairie bluebells. The fire appeared to stimulate these species, with no additional effect of the postfire rehabilitation treatment. Unfortunately, little is known about how these two plants respond to disturbance. Because Fendler's rockcress and prairie bluebells are perennial, we suspect that they may be more persistent on the landscape than the other three disturbance-stimulated species. More work is needed to determine how these two very common species regenerate after fire, and how long they will persist on the landscape over the long-term.

A handful of species were sensitive to the fire $^{+}/$- the postfire rehabilitation treatment, all of which were perennial natives. Nodding onion was sensitive to the fire in general, but not specifically the postfire rehabilitation treatment. This result was unexpected, as nodding onion is known to sprout from a deeply-buried bulb after fire (Stickney and Campbell Jr. 2000). Perhaps an interaction of unfavorable conditions, such as the fire combined with the harsh growing conditions of 2003 and 2004, are responsible for the decrease in nodding onion. Unfortunately, our study design did not allow us to test this hypothesis in our analysis.

The frequency of mountain muhly and yucca was sensitive to the combination of fire and postfire rehabilitation, though percent cover was not. Mountain muhly is a perennial grass that is capable of sprouting after low- and medium-severity fire (Vose and White 1987; Walsh 1995). Yucca is a perennial subshrub or shrub that is capable of sprouting after low- and medium-severity fires, and can also colonize from onsite and offsite sources (Groen 2005). Because frequency was affected but cover was not, it is most probable that individual plants were killed outright, and not that the sprouting response was merely suppressed. While it is not likely that the seeding component of the treatment

could kill individual plants through competition, it is possible that they could be killed by the soil scarification treatment. Whether or not scarifying could kill a plant would depend on the depth of the plant's underground growing points relative to the depth of the scarification treatment. Another possible explanation for this difference in mountain muhly and yucca frequency is burn severity. The burned-and-rehabilitated study site burned slightly hotter than the burned-only study site, and therefore more individual plants could have died in the burned-and-rehabilitated site as a result of greater fire intensity. Unfortunately, we are unable to separate out burn severity effects in our analyses.

Effects on species of concern

We do not expect that the fire $^{+}$/- postfire rehabilitation will have a long-term effect on the two main food sources of the Pawnee montane skipper. While we found that blue grama frequency and cover appeared to be sensitive to the combination of fire and postfire rehabilitation, this finding may also be an artifact of the higher burn severity in the burned-and-rehabilitated site than in the burned-only site. Regardless of why the observed pattern was found, we suspect that the sprouting ability of this plant will allow it to quickly reach or exceed pre-burn levels in the disturbed plots, as has been shown in other studies (Anderson 2003). Dotted blazing star was unaffected by the burn or the postfire rehabilitation treatment.

Data for the three at-risk species— Rocky Mountain Indian parsley, jeweled blazing star, and Front Range milkvetch— were sparse. In fact, Front Range milkvetch could not be analyzed as it was only found in one plot. Statistical analysis of Rocky Mountain Indian parsley and jeweled blazing star indicated that neither was affected by the fire or postfire rehabilitation. However, the relatively low abundance of Rocky Mountain Indian parsley and jeweled blazing star in our plots means that we must be cautious in interpreting these results, especially when so little is known about these relatively uncommon plants.

In our study site plots, we found six plants that are considered noxious weeds by the state of Colorado:

1. Cheatgrass (*Bromus tectorum*),
2. Musk thistle (*Carduus nutans*),
3. Canadian thistle (*Cirsium arvense*),
4. Common St. Johnswort (*Hypericum perforatum*),
5. Butter-and-eggs (*Linaria vulgaris*), and
6. Common mullein (*Verbascum thapsus*).

However, limited frequency and cover data for cheatgrass, musk thistle, and St. Johnswort made statistical analysis unrealistic or impossible for these species. Of the three remaining noxious weeds, we found no effect of fire $^{+}$/- postfire rehabilitation on Canada thistle or butter-and-eggs. Results for mullein are discussed above.

Conclusion and recommendation to land managers

We found that the Hayman Fire had some short-term effects on the understory plant community as a whole and on individual species within the community, but the seed-and-

scarify treatment within the Hayman Fire had little additional effect. This may be the result of low treatment intensity and also of the adaptations that many of the plants have to survive or successfully regenerate after disturbance.

It is not likely that the seed-and-scarify postfire rehabilitation treatment met the goals of the U.S. Forest Service, since the treatment did not appear to reduce erosion. While the composition of the understory did not appear to be affected by seed-and-scarify rehabilitation treatment in the Hayman Fire, results may have been different if the treatment had been significant enough to affect erosion.

Because we did not measure erosion in this study, and because the seed-and-scarify treatment has not been studied in other Front Range fires (or elsewhere), we are uncomfortable with making a recommendation on whether or not local land managers should continue to implement this postfire rehabilitation treatment in the future. However, our results do suggest that this type of treatment needs further scrutiny before it is used extensively under similar conditions. Furthermore, we strongly feel that if Front Range land managers continue to implement this postfire rehabilitation treatment, its effects on the understory plant community must also be monitored to determine the relationship between treatment success and understory response.

Approach

Study Area

Our study sites are in the Upper South Platte Watershed of central Colorado. This area is dominated by ponderosa pine/Douglas-fir forest, with a forest understory that consists of grasses, forbs and shrubs. This area has experienced periodic logging, grazing, and prescribed burning; wildfire suppression policies have been in place since the early 20th century. The Upper South Platte Watershed also experiences heavy recreational use by fishermen, hikers, mountain bikers, off-road vehicle drivers, and horseback riders.

Field data collection

To address our research questions, we compared understory response in unburned, burned-only, and burned-and-rehabilitated study sites. The opportunistic nature of this study did not allow for a completely replicated study design. We were able to replicate the reference study sites, but only one burned and one burned-and-rehabilitated study site could be established. Because of this, it is important to consider potential factors that may complicate comparisons, such as the inherent variability within and between study sites (Hurlbert 1984). We attempted to minimize these factors by establishing the study sites in environmentally similar locations (details below) that are in close proximity to each other, by randomly locating plots and distributing them equally among aspect categories, and by sampling plots randomly throughout the growing season.

In all plots, understory data were collected using the modified-Whittaker method (Stohlgren et al. 1995). In this method, the main plot 1000-m^2 in size, and contains 1-m^2, 10-m^2, and 100-m^2 subplots nested within it. Percent vegetative cover is recorded for each species in the 1-m^2 plots. Cumulative additional species are recorded for each of the

10-m^2 plots, the 100-m^2 plot, and the remainder of the 1000-m^2 plot. Cover data for the 1-m^2 subplots were then averaged to estimate average cover per plot. In addition, the number of individual species in each plot was tallied for all the subplots to estimate species richness for the plot.

Overstory data and ancillary plot information were also collected in each plot. Overstory data were collected for each tree taller than 1.37 m, and measurements included tree diameter at breast height (DBH), species, height, and live or dead status. Ancillary plot data that were recorded included slope, aspect, elevation, and UTM coordinates.

Burned study site: Turkey Creek
The Turkey Creek study site was established in 1996, and fifteen modified-Whittaker plots were randomly located and permanently marked (see Kaufmann et al. 2000 for details). A complete understory and overstory inventory was conducted within each plot, and ancillary data were collected.

In 2002, the Turkey Creek study site burned with variable intensity in the Hayman Fire. According to postfire rehabilitation maps, the majority of the Turkey Creek plots were not rehabilitated after the fire. However, maps indicate that three of the fifteen previously-established plots in Turkey Creek were aerially seeded at a rate of 80 kg/ha, or 280 seeds/ m^2, with a certified weed-free mixture of 70 percent barley and 30 percent triticale after the fire (Robichaud et al. 2003). Preliminary data analysis revealed that the amount of seeded grass germinating in these plots was not significantly higher than in the 'unseeded' Turkey Creek plots— some of the 'unseeded' plots also contained germinated seeded grasses, though it is unknown how the seed reached the area. Because these three plots were not scarified and did not contain more seeded grasses than the other Turkey Creek plots, we consider all the fifteen plots in Turkey Creek to represent the 'burned-only' (i.e., not rehabilitated) condition.

During the summer of 2004, each plot was revisited and complete understory and overstory inventories were conducted again. In 2004, both live and dead seeded grasses were measured because they have the potential to affect understory response when they are alive as well as dead (dead vegetation is not usually measured with the modified-Whittaker technique).

Burned-and-rehabilitated study site: Sheep Nose
Prior to the start of data collection in 2004, we located a new study site for comparison with Turkey Creek. We used GIS coverages to refine the total area treated for rehabilitation after the Hayman burn to a handful of potential sites. These potential sites were selected because they were physically close to Turkey Creek, they were the most comparable in terms of elevation, area, and burn severity, and they were rehabilitated shortly after the fire in 2002. We visited each potential site to evaluate its suitability and accessibility. The final choice, Sheep Nose, is separated from Turkey Creek by only a few kilometers and has comparable attributes.

The rehabilitation treatment at Sheep Nose occurred in the summer/fall of 2002, and was a ground scarify-and-seed treatment. Scarification was done by all-terrain vehicles in areas with less than 20% slope, and by hand where slopes exceeded 20 percent. The seed treatment was a certified weed-free mixture of 70 percent barley and 30 percent triticale. Seed was spread from the ground at a rate of 80 kg/ha, or 280 seeds/ m^2 (Robichaud et al. 2003).

Once the Sheep Nose study site was established, fifteen 0.1-ha plots were randomly located within it. Within each plot, a complete forest understory survey was performed, and both live and dead seeded grasses were measured, as in Turkey Creek. Overstory tree data were also inventoried, and ancillary data were collected at the plot level.

Reference study sites: Sugar Creek, Hatch Gulch, and Manchester Creek
In 2004, we also established and measured three reference study sites in unburned areas to provide information about the pre-fire vegetation condition. These reference sites had not been disturbed in the last five years or had only experienced recent disturbances that were not extreme. In each study site, fifteen plots were randomly located. Understory, overstory, and ancillary plot data were collected for each plot. Plots in these study sites are collectively referred to as reference plots.

<u>Laboratory data collection and data management</u>
Each understory plant name was verified with the U.S. Department of Agriculture's Plants Database (www.plants.usda.gov) to ensure it was the most current name. The growth form (e.g., tree, shrub, forb, grass), duration (e.g., annual, biennial, perennial), and nativity (native or non-native to Colorado) of each plant was also obtained from the USDA Plants Database and/or botanical keys (Harrington 1964; Hitchcock 1971; Weber 1976; Weber and Wittmann 1996). Plant names were recorded only to genus and species; subspecies and varieties were not identified.

<u>Data analysis</u>
We used multi-response permutation procedures (MRPP) to compare the level of each understory response variable between the plots in Turkey Creek, Sheep Nose, and the pooled reference sites (Mielke Jr. and Berry 2001). This method allows for testing between two or more groups and is not limited by assumptions of normally-distributed data or of homogeneous variances, which are assumptions of other statistical tests such as the one-way analysis of variance. MRPP analyses were conducted in Microsoft Excel using a macro developed by Rudy King of the Rocky Mountain Research Station. All statistical tests were evaluated at the alpha=0.05 level.

Deliverables

1. Final report to NCSSF.

2. Manuscript to a peer-reviewed journal. This manuscript will be submitted to Forest Ecology and Management in February 2006 (it is currently in the internal review process at the Rocky Mountain Research Station). It is similar to the technical report listed in (2), but excludes some information that is only of interest to the local land managers (for example, the analysis on 'species of concern'), and is written for a scientific audience.

3. Technical report and PowerPoint summary to forest managers. A technical report and a PowerPoint summary were prepared for Colorado Front Range land managers. The technical report is a full report of our research objectives, methods, findings, and recommendations. The full PowerPoint presentation provides an overview of the technical report, which managers can use if they desire. The technical report and the PowerPoint summary will be posted on our web site (www.fs.fed.us/rm/analytics/staff/fornwalt.html), and copies will also be sent to interested land managers throughout the Colorado Front Range. We will also meet with land managers at their request to present the material or to go over any questions they may have.

4. Presentations at relevant meetings and conferences. Paula Fornwalt presented the research findings at the Annual Front Range Fuels Treatment Partnership Implementation Meeting on January 18, 2006, where approximately 100 Colorado Front Range land managers and researchers from multiple agencies were present. Paula will also present these findings at the Disturbance Symposium in April 2006.

5. Non-technical articles to periodicals read by targeted users. Two non-technical articles were prepared for targeted users and will be published in early 2006. These articles will be published in newsletters for the Coalition for the Upper South Platte and the Colorado Native Plant Society.

References

Anderson, M.D., 2003. *Bouteloua gracilis*. Fire Effects Information System [www.fs.fed.us/database/feis/]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory [December 2005].

Bartos, D.L., Mueggler, W.F., 1981. Early succession in aspen communities following fire in western Wyoming. J. Range Manage. 34, 315-318.

Beyers, J.L., 2004. Postfire seeding for erosion control: effectiveness and impacts on native plant communities. Conserve. Biol. 18, 947-956.

Brown, P.M., Kaufmann, M.R., Shepperd, W.D., 1999. Long-term, landscape patterns of past fire events in a montane ponderosa pine forest of central Colorado. Landscape Ecol. 14, 513-532.

Finney, M.A., McHugh, C.W., Bartlette, R., Close, K., Langowski, P., 2003. Description and Interpretations of Fire Behavior. In: Graham, R.T. (Ed.), Hayman Fire Case Study. General Technical Report RMRS-GTR-114. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO, pp. 59-95.

Fornwalt, P.J., Kaufmann, M.R., Huckaby, L.S., Stoker, J.M., Stohlgren, T.J., 2003. Non-native plant invasions in managed and protected ponderosa pine/ Douglas-fir forests of the Colorado Front Range. For. Ecol. Manage. 177, 515-527.

Groen, A.H., 2005. Yucca glauca. Fire Effects Information System [www.fs.fed.us/database/feis/]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory [January 2006].

Halpern, C.B., 1989. Early successional patterns of forest species: interactions of life history traits and disturbance. Ecology 70, 704-720.

Harrington, H.D., 1964. Manual of the plants of Colorado. Swallow Press, Inc., Chicago, IL.

Hitchcock, A.S., 1971. Manual of the grasses of the United States. Dover Publications, New York, NY.

Hurlbert, S.H., 1984. Pseudoreplication and the design of ecological field experiments. Ecol. Monogr. 54, 187-211.

Kaufmann, M.R., Regan, C.M., Brown, P.M., 2000. Heterogeneity in ponderosa pine/Douglas-fir forests: age and size structure in unlogged and logged landscapes of central Colorado. Can. J. For. Res. 30, 698-711.

Kaufmann, M.R., Fornwalt, P.J., Huckaby, L.S., Stoker, J.M., 2001. Cheesman Lake- a historical ponderosa pine landscape guiding restoration in the South Platte Watershed of the Colorado Front Range. In: Vance, R.K., Covington, W.W., Edminster, C.B. (Eds.), Ponderosa Pine Ecosystems Restoration and Conservation: Steps Toward Stewardship.

US Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO. Proceedings RMRS-P-22, Flagstaff, AZ, pp. 9-18.

Mielke Jr., P.W., Berry, K.J., 2001. Permutation methods: A distance function approach. Springer, New York, NY.

Robichaud, P., MacDonald, L., Freeouf, J., Neary, D., Martin, D., Ashmun, L., 2003. Postfire rehabilitation of the Hayman Fire. In: Graham, R.T. (Ed.), Hayman Fire Case Study. General Technical Report RMRS-GTR-114. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO, pp. 293-313.

Rutledge, C.R., McLendon, T., 1996. An Assessment of Exotic Plant Species of Rocky Mountain National Park. Department of Rangeland Ecosystem Science, Colorado State University. Jamestown, ND: Northern Prairie Wildlife Research Center Online. http://www.npwrc.usgs.gov/resource/plants/explant/explant.htm (Version 15DEC98). [January 2006].

Stickney, P.F., 1990. Early development of vegetation following holocaustic fire in Northern Rocky Mountain Forests. Northwest Sci. 64, 243-246.

Stickney, P.F., Campbell, R.B. Jr., 2000. Data base for early postfire succession in Northern Rocky Mountain Forests. General Technical Report RMRS-GTR-61CD. US Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.

Stohlgren, T.J., Falkner, M.B., Schell, L.D., 1995. A modified-Whittaker nested vegetation sampling method. Vegetatio 117, 113-121.

U.S. Fish and Wildlife Service, 1998. Pawnee montane skipper butterfly (*Hesperia leonardus montana*) recovery plan. Denver, CO.

Vose, J.M., White, A.S., 1987. Processes of understory seedling recruitment one year after prescribed fire in an Arizona ponderosa pine community. Can. J. Bot. 65, 2280-2290.

Walsh, R.A., 1995. *Muhlenbergia montana*. Fire Effects Information System [www.fs.fed.us/database/feis/]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory [December 2005].

Wang, G.G., Kemball, K.J., 2005. Effects of fire severity on early development of understory vegetation. Can. J. For. Res. 35, 254-262.

Weber, W.A., 1976. Rocky Mountain Flora. University Press of Colorado, Niwot, CO.

Weber, W.A., Wittmann, R.C., 1996. Colorado Flora: Eastern Slope. University Press of Colorado, Niwot, CO.

Appendix 1. Links to project websites

Documents related to this project will be posted on the Rocky Mountain Research Station's website at www.fs.fed.us/rm/analytics/staff/fornwalt.html.

Appendix 2. List of publications

Fornwalt, P.J. and M.R. Kaufmann. Short-term effects of fire and postfire rehabilitation on the forest understory: a case study from the Colorado Front Range. To be submitted to Forest Ecology and Management, February 2006.